Selection and Monitoring of Avian Indicator Species: An Example From a Ponderosa Pine Forest in the Southwest

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Abstract

A critical discussion of the factors involved in selecting an indicator species is highlighted by the examination of a case study. The pygmy nuthatch and violet-green swallow are suggested as indicator species for lightly cut to old growth southwestern ponderosa pine. The monitoring of avian species could best be accomplished by the variable circular-plot method.

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Management Implications

New rules and regulations set forth in section 219.12 on Forest Planning Actions (Federal Register 1979) require the USDA Forest Service to develop forest plans that will maintain viable populations of all existing native vertebrate species in planning areas and to maintain and improve habitat of management indicator species.

In selecting bird species for use as indicator species, land managers should consider several factors: (1) Residency status (i.e., summer, winter, or permanent resident), (2) foraging and/or nesting substrate, (3) adequate data base, (4) ease of monitoring, (5) sensitivity to habital perturbations, (6) sensitivity to environmental fluctuations, (7) the condition or range of conditions a given species will "indicate," and (8) biogeographic considerations based on fragmentation of the habitat. Rare species may need to be used in the eighth case. Unfortunately, although limited information on many species precludes their selection as indicators, regulations require species to be selected in a relatively short period of time without the luxury of additional research to help in this process. Therefore, forest biologists and researchers with many years experience in a particular locality should base the selection on the best available information by both. It is unrealistic to expect a forest biologist with limited experience on a given forest to select species that might best indicate habitat degradation or condition.

Many forests within a given region have similar types of habitats. Forest biologists conferring among themselves and consulting with university personnel and other source agencies (e.g., U.S. Fish and Wildlife Service, State Game and Fish Departments) should be able to choose several species to meet the previously mentioned criteria. The species selected should always be considered as being on probation; that is, new data should be used to cull species from and add species to the list. When possible, managers within a region should attempt to select the same species within similar habitats.

Many methods of estimating bird numbers have been tried with varying degrees of success. We believe that a new technique, the variable circular-plot method, should be used for monitoring avian indicator species. This method has the advantages of (1) ease of setting up the plot, (2) accurate determination of sampling effort, (3) more accurate relation of habitat correlates to bird species and numbers, and (4) elimination from density estimations of the time spent watching the path of travel.

Introduction

As defined by the regulations, indicator species include at least: (1) Endangered and threatened plant and animal species, (2) species commonly hunted, fished, or trapped, (3) species with special habitat needs, and (4) additional plant or animal species selected because their population changes are believed to indicate effects of management activities on the collective species of a major biological community or on water quality.

Species in the first two categories have already been defined for the land manager: Threatened and endangered species appear on federal and state lists, and the species subject to hunting, fishing, and trapping are determined by state departments of fish and game. The land manager should be sure to use the current versions of such lists. When choosing species within these categories as indicators, the land manager should also apply the same general considerations used in the following example of selecting avian indicators in a Southwest ponderosa pine (*Pinus ponderosa*) forest.

We will concentrate on the selection of indicator species in the third and fourth categories, where species are selected because their population changes are indicative of management effects on an entire biological community or because of special habitat needs that must be met for their survival. These species serve as an "early warning system" of habitat changes because they are among the first species to respond to changes in habitat or because they respond to the smallest increments in change in habitat. Usually the manager must select more than one species of indicator in this category because any single species can serve as an indicator for only a narrow range of ecological conditions within a habitat type. For example, if an understory species were the only indicator species chosen for a ponderosa pine forest, inventories taken after heavy modification of the overstory would fail to show any effects of the treatment on overstory species. Thus, the manager must choose indicator species on the basis of the specific habitat factors which must be monitored. Because decisions based on the response of these indicator species may affect forest practices employed for a decade or longer, errors in selecting such species may have long-term negative effects on forest structure and animal community structure.

An ideal indicator species should (1) be sensitive to habitat-induced stress, (2) be conspicuous by sight and sound, (3) be easy to recognize in the field without the observer having to capture the species to identify it, and (4) operate during the hours when man is active. These attributes are most evident in birds; therefore,

this paper deals with the selection and monitoring of birds as indicator species.

The relationship between habitat perturbation and avian population trends is an area of past and current research effort. Habitat alterations in the form of timber harvest (Hagar 1960, Kilgore 1971, Franzreb 1977, Szaro and Balda 1979a), burning (Marshall 1963, Bock and Lynch 1970), and other means (Karr 1968, Yeager 1955), have had a demonstrable effect on bird community structure. It now becomes critical to draw on all the available information to select viable indicator species from those species that reflect these effects.

In this paper we will examine two critical aspects of the indicator species problem. First, given the adequate data, how to choose those species best suited as indicators and, second, how to monitor avian species once they are selected as indicators.

Indicator Species Selection in Ponderosa Pine

The primary prerequisite for selecting an indicator species is to define the conditions and/or health of the community you wish to indicate. Bird species can be selected whose presence is indicative of forest conditions from old growth forests to clearcuts.

In the ponderosa pine forest, the forest manager has a degree of latitude in choice and application of timber harvest prescriptions (Szaro and Balda 1979b). The opening of dense canopy forests has been shown to increase bird species and abundance in Douglas-fir (*Pseudotsuga menziesii*), giant sequoia (*Sequoiadendron giganteum*), and ponderosa pine (Hagar 1960, Kilgore 1971, Szaro and Balda 1979a). However, the quality of the bird community changes with forest structure.

Species such as the hermit thrush,[2] red-faced warbler, western flycatcher, and pygmy nuthatch, found in old growth forest and only lightly disturbed areas, are replaced in moderately to heavily cut areas by species such as the western wood pewee, yellow-rumped warbler, and rock wren. Those species that are most sensitive to habitat perturbations potentially make the best indicator species.

An examination of 2 years of data from four different study sites reveals an array of species responses to habitat manipulation (table 1). Many breeding species found in ponderosa pine stands throughout Arizona—Coues flycatcher, acorn woodpecker, band-tailed pigeon, Virginia's warbler, pygmy owl, whip-poor-will, goshawk, brown creeper, Brewer's blackbird, pine siskin, olive warbler, Say's phoebe, and hepatic tanager—are too rare to be of any help as general community indicators (Balda 1969, Carothers et al. 1973, Szaro 1976). However, they may be useful as indicators of special habitat needs, such as the close association between acorn woodpeckers and Gambel oak (*Quercus gambelii*) (MacRoberts and MacRoberts 1976), or of special biogeographic considerations, as is the coppery-tailed trogon.

[2]*Scientific names of birds are listed in the appendix.*

Table 1.—Habitat preferences and densities (2-year average— pairs per 100 acres) of avian species in selected ponderosa pine forest stands in Northern Arizona

Preference and species	Untreated[a]	Silviculturally cut	Irregular strip cut	Severely thinned cut
No preference				
Common flicker	3.0	3.0	3.4	3.0
Hairy woodpecker	3.0	3.0	4.5	2.3
Steller's jay	7.5	4.5	5.3	5.3
Common nighthawk	3.0	1.5	3.0	3.0
Mourning dove	3.0	1.5	—	5.3
White-breasted nuthatch	6.8	11.3	10.5	7.5
Prefer nondisturbed or lightly disturbed areas				
Red-faced warbler	3.0	—	—	—
Hermit thrush	1.9	0.4	—	—
Western flycatcher	4.9	4.2	—	—
Pygmy nuthatch	14.3	16.5	6.0	1.9
Violet-green swallow	8.3	8.3	3.0	—
Black-headed grosbeck	3.3	3.0	1.5	—
Prefer nondisturbed or moderately disturbed areas				
Gray-headed junco	15.0	18.8	11.3	6.4
Mountain chickadee	5.3	5.3	4.5	0.8
Prefer moderately to heavily disturbed areas				
Western wood pewee	—	2.3	9.0	3.0
Robin	—	3.0	5.3	3.8
Broad-tailed hummingbird	6.0	4.1	12.0	9.8
Prefer heavily disturbed habitat				
Rock wren	—	—	7.2	4.5
Prefer lightly or moderately disturbed areas				
Grace's warbler	9.0	19.1	14.3	6.8
Yellow-rumped warbler	1.5	12.0	3.0	1.5
Western tanager	1.5	5.6	3.0	—
Western bluebird	4.5	7.9	13.5	5.8
Prefer lightly to heavily disturbed areas				
Chipping sparrow	2.3	6.0	9.0	4.5
Solitary vireo	3.0	6.0	9.0	6.0
Prefer oak groves				
Acorn woodpecker	—	—	—	3.0

[a]*See Szaro and Balda (1979b) for a more complete description of the study areas. Areas are listed in order of descending foliage volume.*

Before we can make any decision on community indicators, we need to review current timber management practices in southwestern ponderosa pine stands. The commonly used silvicultural system in southwestern ponderosa pine today is the shelterwood system (Schubert 1974). This system is designed to produce even-aged stands. However, with prior planning, timber management activities in southwestern ponderosa pine can generally provide multiple use benefits (Brown et al. 1974).

A frequent objective of timber management is the highest possible sustained timber yield (Schubert 1974). The shelterwood system involves managing each stand at a growing stock level of 60 square feet basal area per acre. At the first year of a new rotation there should be 25 trees averaging 22-24 inches in diameter. Eleven trees per acre will be marked to be left for shelter and as a seed source (about 40 square feet basal area). The remaining 14 trees will be removed. After a regeneration period of 10 years the overstory will be removed. At the 20th year, the new stand will average 1 inch in diameter and will be commercially thinned to 60 square feet. Subsequent intermediate cuts, starting with a commercial thinning at age 40, follow at 20-year intervals until the 120th year, when the rotation is complete.

Timber management using the shelterwood system requires a considerable time span (approaching 60 years) before the trees average 11 inches in diameter and before one can expect a managed stand to contain most of the bird species found in a community. It probably is advisable to schedule stand treatments to avoid extensive adjacent areas within the first 60 years of rotation. A minimum stocking level of 54 square feet per acre is necessary to maintain bird densities and diversity in the ponderosa pine forest with undisturbed or only lightly thinned areas surrounding the periphery of much of the cut area (Szaro and Balda 1979b).

What species will best indicate the overall "health" of a bird community in a given ponderosa pine stand? We answer this question by examining the core species (those found on four or more sites and/or years) in a stand with a minimum of 60 square feet basal area per acre. Ideally, we need a mix of 2, 3, or 4 species with differing requirements for foraging, nesting, and wintering areas. We can narrow our selection by determining the sensitivity of species to changes in habitat structure (table 1). Six species, Steller's jay, common nighthawk, common flicker, hairy woodpecker, white-breasted nuthatch, and mourning dove, are insensitive to most levels of habitat disturbance short of total foliage removal. Obviously these species would make poor indicators. Other core species that probably would be poor indicators because of their scattered occurrence throughout structural types are listed in table 1.

One can argue against selecting summer residents because their populations can be highly influenced by winter weather conditions on and off the breeding grounds during the nonbreeding season (Fretwell 1972). This is not to imply that permanent residents are not affected by winter weather, but that their breeding or summer densities might be modified by habitat quality (Kricher 1975). Permanent residents are species whose densities are determined primarily by the habitat configuration of the pine forest (Balda and Gaud[3]). Summer residents, in contrast, make only a brief 3-month appearance that occurs during a peak in productivity of various food types during spring and summer. Productivity appears to be closely correlated with prior winter weather conditions. Thus, the densities of summer residents may reflect prior winter conditions.

Similarly, one can argue against including either foliage or ground nesting species, as few species of permanent resident birds in the ponderosa pine forests are not cavity nesters and those that are not, are poor indicators. For example, the Steller's jay is found throughout the ponderosa pine forest with no discernable preference to any particular habitat configuration. Thus, although limiting the possible choices of species to permanent resident, cavity nesting species might be overly restrictive in that the number of species to choose from is reduced, it is our view that these species are more likely to reflect actual changes in habitat conditions.

Species with low densities, even though some exhibit definite habitat preferences and may be good indicators, would be difficult to monitor. What needs to be guaranteed is that the species finally selected is an indicator of these "rarer" species.

An exception to picking a summer resident or a species with low density would occur when the manager wants to indicate a very narrow range of conditions within a vegetative association. Noon et al. (1979) suggest that extensive habitat disturbance may have its most pronounced effects on the rare species of a community. Thus, the determination of habitat features which support these rare species should be of prime importance. Their consistent rareness even in their preferred habitat is indicative of an extreme specialization to some aspect of their environment (Noon et al. 1979). For example, two rare species, the western flycatcher and hermit thrush, are both excellent indicators of old growth forest with a dense overstory.

A close examination of permanent resident cavity nesters with adequate densities for a sampling program narrows the possible choices to two: (1) pygmy nuthatch and (2) violet-green swallow. Both are relatively easy to observe and census. Balda and Gaud[3] developed models to predict density and diversity of breeding birds in the ponderosa pine forest (using the data from table 1 and several other sites). When 10 weather factors and 11 factors of foliage structure were used in a multiple regression analysis, no weather factors entered into the model for either the pygmy nuthatch or the violet-green swallow. In fact, 83% of the variability in pygmy nuthatch densities was explained by total foliage volume (63.4%), snag density (11.6%), and trunk volume (7.8%). Both foliage volume and snag density were positively associated, whereas trunk volume was negatively associated, with pygmy nuthatch density. In contrast, three negatively associated factors, Gambel oak foliage volume (66.3%), trunk volume (9.7%), and sapling volume (16.7%), predicted 93% of the variability in violet-green swallow density. Therefore, in choosing these two species we are selecting for a ponderosa pine stand with high foliage volume and snag densities with little Gambel oak and few pine saplings. These are the same factors necessary to

[3]*Balda, Russell P., and William S. Gaud. 1980. A model to predict density and diversity of breeding birds in the ponderosa pine forest. Northern Arizona University, Flagstaff, Ariz., and Rocky Mountain Forest and Range Experiment Station, Tempe, Ariz. Unpublished manuscript.*

maintain the populations of most other typical ponderosa pine breeding birds.

Other species can be used to indicate other habitat conditions. For example, the rock wren is only present on heavily disturbed or clearcut habitats. Moreover, the western wood pewee might be considered as an indicator of the bird community in more open ponderosa pine stands.

We should emphasize that in our selection process we are chosing species that are indicative of a particular set of habitat conditions. Then we are looking at what species are found under the same set of conditions. The correlation between the density of the indicator species and other species of the avian community is not directly established by this method. However, an examination of the density data (table 1) shows that, when we have good densities of pygmy nuthatch and violet-green swallow, we also have good densities of most other ponderosa pine forest bird species.

Species Monitoring Methods

How best to estimate bird populations is a question still embroiled in controversy. Currently the two most widely accepted techniques are the territory mapping method (Williams 1936, Kendeigh 1944, Enemar 1959) and the line transect method (Emlen 1971, 1977; Järvinen 1976, 1978; Järvinen and Väisänen 1975, 1976a, 1976b; Järvinen et al. 1976). The territory mapping method is sometimes considered the most accurate means of estimating population densities of breeding territorial birds (see Best 1975 for discussion of its limitations). However, its use (by definition) is limited to the breeding season and is not applicable in censusing bird populations in the nonbreeding seasons (Franzreb 1977). The line transect method can be used any time of the year but usually requires a census line of at least a mile in length. The required length of the transects is a problem in many small "island" habitats or in habitats with heterogeneous or patchy structure. Additionally, it is virtually impossible to obtain confidence limits on bird population estimates from the territory mapping method, and difficult at best with the line transect method to sample enough transect lines to get a valid statistical estimate (Eberhardt 1978, Burnham et al. 1980). Certainly by increasing the number of visits in both techniques, the researcher can improve the efficiency and accuracy of the technique (Järvinen et al. 1978, Svensson 1978).

Reynolds et al. (1980) developed a new technique, the variable circular-plot method, which may prove to be the best method to monitor indicator species. Briefly, the technique involves establishing stations within a plant community at equal intervals along a transect or scattered within a habitat type (avoiding edges) in such a manner as to avoid multiple detections of the same bird at different stations. The observer records each bird seen or heard during the count period (8 minutes for closed canopy forests) and estimates the horizontal distance to its location when first observed. The density of each species is then determined by inspecting a histogram of the number of individuals per unit area in concentric bands of predetermined widths about the stations. An inflection point (i.e., the distance from the point where the density begins to decline) is determined, and the number of individuals occurring within this distance (radius X) is divided by area of radius X to estimate birds per unit area. Bird abundance measures must be keyed to an area of given size and not a relative index that does not take into account detectability differences, such as in the study by Webb et al. (1977).

Determination of the number of stations and/or sampling periods per station is based on the habitat, species abundance, and the size of the area to be sampled. For example, in Hawaii, density estimates of ±30% of mean density for most common species were obtained by sampling 56 stations or less (Reynolds et al. 1980). For rarer species, 210 stations were needed for density estimates of ±50% of mean density. For a ±30% estimate, 622 stations were required. A reduction in the number of stations required can be obtained by multiple sampling of the same stations. But, because of the correlation between estimates taken at the same station, the fewer times a given station is sampled the better the estimate of variability. Therefore, the number of stations sampled must carry most of the weight in developing estimates of precisions likely to be achieved with a given level of sampling. We recommend not sampling the same station more than three times. Obviously, there are tradeoffs involved in trying to determine the optimum number of stations and the number of times each station should be sampled. If the object of the sampling is to determine breeding bird abundance, then a single sample at a large number of points all sampled on the same day early in the breeding season would fail to estimate late breeding species. The converse is also true. For example, sampling a desert scrub habitat in late May would fail to census the male Costa's hummingbirds displaying on the plot. Any bird sampling design, therefore, should incorporate a combination of both a representative number of stations for a given area and either repetitive sampling at each station or, preferably, sampling different points in the same habitat at various times throughout the breeding season. For yearly trend information, data should be collected within a relatively tight time frame (i.e., a month) from one year to the next.[4]

In desert riparian and scrub habitats, Szaro and Jakle found that 14 stations sampled 4 times at 2-week intervals were sufficient to obtain density estimates of ±50% for 13 of the 23 breeding species on both study plots. Half the estimates were within ±30% of mean density. A greater number of sampling periods and/or sampling stations would have been necessary to obtain more accurate density estimates. However, no increase in the number of stations was possible in the desert riparian plot because of the limited size of the riparian area. An obvious question is how these esti-

[4]*Personal communication with Jared Verner, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Fresno, Calif., 1981.*

mates compare to those obtained by more accepted techniques (i.e., the spot-map and line transect methods). Szaro and Jakle[5] reported that, in desert riparian and scrub habitats sampled by both the spot map and variable circular-plot methods, all the spot map densities except one fell within the 95% confidence limits of their variable circular-plot estimates.

The variable circular-plot method has several advantages: (1) canopy birds can be more accurately censused because the observer is stationary and not spending time watching the path of travel; (2) habitat correlates at each station can be more accurately related to species abundance or absences because the areas censused are smaller and more discrete than with the other two methods; and (3) the sampling effort can be more accurately determined.

The application of the variable circular-plot method is as follows:

1. Determine the relative abundance of the species to be monitored. For example, common (more than 120 individuals/100 acres) or rare (fewer than 10 individuals/100 acres).
2. The number of stations required to establish the abundance of a species varies with the spatial distribution of individuals within a population, their abundance, and their conspicuousness in each season and habitat. We recommend that up to 56-64 stations be censused and then density estimates calculated. Sampling should be continued until the percent variation around the mean density reaches an acceptable level, i.e., 10, 20, or 30%. The sampling scheme should be designed so that more stations could be added properly if the need arises. The intensity of the sampling effort throughout the area in question must be maintained even as new stations are added.
3. Determine points at random throughout the habitat or on transect lines at a minimum of 350-foot intervals.
4. Sample each station by first waiting 1 minute and then recording the distance from the point to each bird seen or heard during 8-minute periods (closed habitat as a ponderosa pine association) or during 4-minute periods (open habitat such as a palo verde-saguaro (*Cercidium microphyllum-Cereus giganteus*) association). In practice, the time period should depend upon the detectability of the birds within each habitat.
5. Plot the density of a species in bands of 15-foot widths from 0 to 330 feet and then 30-foot widths from 330 to 660 feet (table 2). Singing males count as two individuals. Density per band is then calculated by the following formula:

$$BD = \frac{4.356\ (10^6)\ (N)}{\pi\ (OR^2 - IR^2)\ (p)\ (f)}$$

where BD = band density on a 100 acre scale, N = number of observations in the band, OR = the outer band radius, IR = the inner band radius, p = the number of sampling stations, and f = the frequency each station was sampled.

6. Determine the inflection point (IP). That is, determine the distance to the outermost edge of the band where the density of individuals per unit area (100 acres) in the next outermost band is less than 50% of the previous band. However, if the number of individuals per 100 acres in any one of the more distant bands exceeds 50% of the mean number of birds per 100 acres per band over all preceding bands, then, in this case, use this outermost edge of this band as the inflection point. Caution should be taken against the blind application of this method. The inflection point should be determined after a careful analysis of the data. As an alternative, Ramsey[6] suggests plotting a cumulative frequency curve of the data and then determining the density estimate from the point of maximum slope of the curve. In our example in table 2, the inflection point is 90 feet.
7. The inflection point (determined separately for each species) is then used to calculate birds per 100 acres for each point for each count period. Use the formula:

$$\text{birds/100 acres} = \frac{4.356\ (10^6)\ (N)}{\pi\ (IP^2)}$$

8. Overall density is then calculated by determining the mean ($\bar{y}$) and standard error (SE) of the individual estimates. In order to account for the correlation between sampling periods, SE should be calculated by the following:

$$v(\bar{y}) = \left(\sum_{i}^{f} S_i^2 + 2 \sum^{f} \sum^{f}_{i<j} r_{ij} S_i S_j \right) \Big/ (pf^2)\ ;\ SE = \sqrt{v(\bar{y})}$$

Where S_i^2 is the among-station variance on the i^{th} sampling period, and r_{ij} is the correlation between sampling periods i and j. For our example, overall density of Lucy's warbler is 428 ± 97 birds/100 acres (table 3).

The variable circular-plot technique has the further advantage of probably being adaptable to censusing other vertebrate species. For example, the stations can be used as central locations for small mammal population estimates by modifying existing methods and setting live traps in a concentric pattern around the census point (Marten 1970, Nelson and Clark 1973, Geier and Best 1980, Seber 1973). Similarly, small reptiles and amphibians can be sampled using an array system of pit traps (Seber 1973, Heckel and Roughgarden 1979, Jones 1980).

In areas of larger, more uniform, and less complex habitats the line transect or strip count method might be considered an acceptable alternative because it allows the coverage of larger areas per unit of time (see Burham et al. 1980 and Eberhardt 1978).

[5] *Szaro, Robert C., and Martin D. Jakle. 1981. Comparison of variable circular-plot and spot-map methods for estimating avian densities in desert riparian and scrub habitats. Rocky Mountain Forest and Range Experiment Station, Tempe, Ariz. Unpublished manuscript.*

[6] *Personal communication with Fred Ramsey, Oregon State University, Corvallis, 1980.*

Table 2.—Hypothetical example of data for Lucy's warbler obtained from seven variable circular-plot stations, each sampled twice

Interval	Observations: Singing males	Observations: Others	Total	Band[a] density
feet				
0< 15	1	1	3	1320
15< 30	1	3	5	734
30< 45	2	3	7	616
45< 60	3	2	8	503
60< 75	2	2	6	293
75< 90[b]	2	2	6	240
90< 105	1		2	68
105< 120	1		2	59
120< 135				0
135< 150	1		2	46
150< 165				0
165< 180				0
180< 195	1		2	35
195< 210				0

Station	Observations: Sampling period	Observations: < 90 feet	Density[a]
1	1	3	514
	2	4	685
2	1	2	342
	2	2	342
3	1	2	342
	2	1	171
4	1	3	514
	2	5	856
5	1	0	0
	2	1	171
6	1	2	342
	2	1	171
7	1	2	342
	2	7	1198

[a]*Birds per 100 acres*
[b]*Inflection point*

Table 3.—Example mean and standard error calculation for Lucy's warbler density (from data in table 2)

Computation Steps

1. Correlation between sampling periods 1 and 2 (see Sokal and Rohlf 1973, page 271).

$$r_{ij} = 0.49$$

2. Calculate mean ($\bar{y}$) and standard deviation (s) for both sampling periods.

$$\bar{y}_1 = 342.29 \qquad s_1 = 171.33$$
$$\bar{y}_2 = 513.43 \qquad s_2 = 407.55$$

3. Overall mean.

$$\bar{y} = \tfrac{1}{2}(\bar{y}_1 + \bar{y}_2) = 427.86$$

4. Overall standard error.

$$v(\bar{y}) = [(171.33^2 + 407.55^2 + 2 \times (0.49) \times (171.33) \times (407.55)] / (7 \times 2^2)$$
$$= 9474.2$$
$$SE = \sqrt{9474.2} = 97.3$$

Conclusions

The management of forest lands requires a multiple use approach which is not inconsistent with maintaining viable bird populations. Species sensitive to habitat perturbations will be the best indicators. Preferably, they should include species with densities more influenced by habitat rather than environmental factors and species with high enough densities for a monitoring program to yield more than just simple presence or absence data. In the ponderosa pine forest, we suggest that the two species that best indicate the overall "health" of the bird community are the pygmy nuthatch and violet-green swallow.

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Appendix

Bird Common and Scientific Names

Common Name	Scientific Name
Band-tailed pigeon	*Columba fasciata*
Mourning dove	*Zenaida macroura*
Pygmy owl	*Glaucidium gnoma*
Whip-poor-will	*Caprimulgus vociferus*
Common nighthawk	*Chordeiles minor*
Costa's hummingbird	*Calypte costae*
Broad-tailed hummingbird	*Selasphorus platycercus*
Coppery-tailed trogon	*Trogon elegans*
Common flicker	*Colaptes auratus cafer*
Acorn woodpecker	*Melanerpes formicivorous*
Hairy woodpecker	*Picoides villosus*
Say's phoebe	*Sayornis saya*
Western flycatcher	*Empidonax difficilis*
Coue's flycatcher	*Contopus pertinax*
Western wood pewee	*Contopus sordidulus*
Violet- green swallow	*Tachycineta thalassina*
Steller's jay	*Cyanocitta stelleri*
Mountain chickadee	*Parus gambeli*
White-breasted nuthatch	*Sitta carolinensis*
Pygmy nuthatch	*Sitta pygmaea*
Brown creeper	*Certhia familiaris*
House wren	*Troglodytes aedon*
Rock wren	*Salpinctes obsoletus*
American robin	*Turdus migratorius*
Hermit thrush	*Catharus guttatus*
Western bluebird	*Sialia mexicana*
Solitary vireo	*Vireo solitarius*
Virginia's warbler	*Vermivara virginiae*
Olive warbler	*Peucedramus taeniatus*
Yellow-rumped warbler	*Dendroica coronata auduboni*
Grace's warbler	*Dendroica graciae*
Red-faced warbler	*Cardellina rubrifrons*
Brewer's blackbird	*Euphagus cyanocephalus*
Western tanager	*Piranga ludoviciana*
Hepatic tanager	*Piranga flava*
Black-headed Grosbeak	*Pheucticus melanocephalus*
Pine siskin	*Carduelis pinus*
Gray-headed junco	*Junco caniceps*
Chipping sparrow	*Spizella passerina*

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Agriculture—CSU, Fort Collins

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A critical discussion of the factors involved in selecting an indicator species is highlighted by the examination of a case study. The pygmy nuthatch and violet-green swallow are suggested as indicator species for lightly cut to old growth southwestern ponderosa pine. The monitoring of avian species could best be accomplished by the variable circular-plot method.

Keywords: Indicator species, ponderosa pine, monitoring methods, variable circular-plot method

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U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

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